# International Space Station Power System Telemetry Compared With Analytically Derived Data for Shadowed Cases

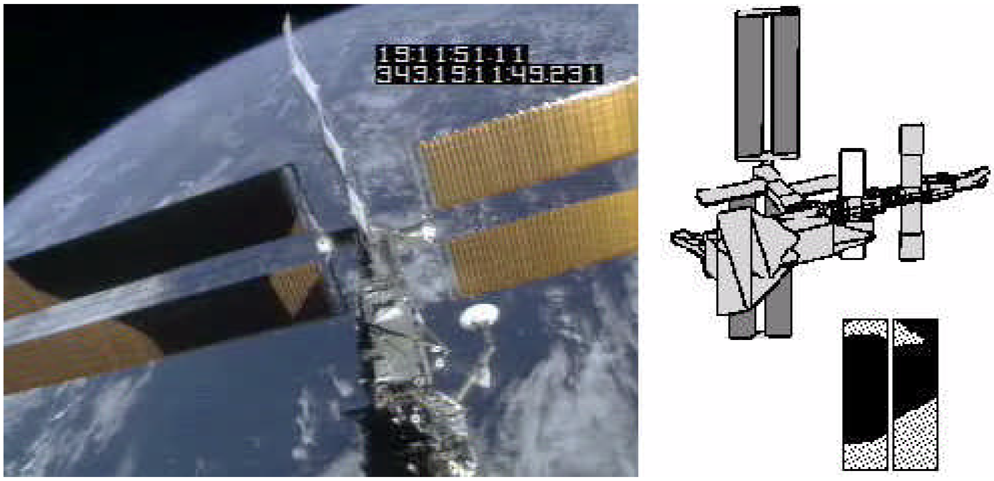
This article highlights fiscal year 2002 work performed by NASA Glenn Research Center personnel to validate algorithms and data developed in-house to predict shadowing effects on the International Space Station (ISS) solar arrays' power generation. The validation effort utilized video footage and on-orbit telemetry for cases spanning a 1-yr period. Validation was required because of the uncertainty of various aspects involved in shadowing analysis. Results show that a good comparison exists between actual and predicted shadowed power system performance for solar array front and backside shadowing.

In December 2000, the first ISS U.S. solar arrays were deployed. Since then, some of the largest shadow patterns ever observed on orbital solar arrays (~170 $m^2$) have occurred. Shadow patterns with significant durations and varied shapes have appeared. Power demands and shadowing events will increase in frequency and magnitude in a complex fashion that can only be predicted by computer program such as the Glenn-developed power system tool called SPACE (System Power Analysis for Capability Evaluation). SPACE models the power hardware and integrates all analysis components (e.g., shadowing analysis) to determine the time-varying effect of load demand on the power system.

The development of the SPACE shadowing algorithms and geometry data required key assumptions: (1) that relatively low fidelity geometry models were acceptable (instead of highly detailed, but computationally prohibitive models), (2) that the Sun could be modeled as a point light source, and (3) that reflected energy from adjacent hardware was minimal.

Each year, the ISS travels through over 5500 orbits, with various flight attitudes, solar array pointing, and space shuttle docking locations. Since most orbits have some shadowing and analyzing every orbit is time prohibitive, only portions of orbits with adequate video documentary footage and recorded telemetry and that showed a significant effect of the shadow on the power were examined.

Acquiring telemetry data and correlating it with predictions is complicated because of data dropouts, sensor calibration, data conversion, and unsensored data. Also, because reflected sunlight from the Earth's surface affects the comparison (the exact amount is unknown), a range of values representing likely short term values were examined.




*Video frame and SPACE-generated geometry and shadow patterns.*

Long description of figure On the left side of the image is a video frame, captured from a space shuttle camera, which shows the shuttle's shadow being cast onto an ISS solar array. The ISS was in a free-drift mode performing a structural test while the shuttle was attached to it. Because of the camera angle, the ISS appears to be at a 10-degree angle (uphill slope from left to right) in the image. In the foreground, on the left of the image, is about 70 percent of the starboard ISS solar array, and on the right is about 30 percent of the port ISS solar array. Also shown are the forward ISS radiator and the structural support truss for the power system. The shadow of the shuttle covers most of the starboard solar array in the image (about 80 percent) and is induced by the shuttle wings and payload bay/payload bay doors. On the right side of the image are SPACE-generated geometry and shadow patterns derived from the ISS operational telemetry. One shows a cartoon-like figure of the ISS as seen from the Sun. The entire ISS vehicle is shown. Although the viewpoint is not from the shuttle camera perspective, it is evident from the image that a good comparison exists between the video and SPACE. The other image is the shadow pattern determined by SPACE for the time step depicted. There are two rectangular blocks (of the shadowed solar array wing) showing a gray shade when illuminated by the Sun and black when shadowed. The shadow pattern appears to match the video frame closely.

The figure shows a selected video frame and SPACE graphical output (a cartoon of the array from the Sun's viewpoint and the projected shadow pattern of one set of solar arrays) for one of the five analyzed cases. During this period, the ISS drifted 180° about one axis, causing the back of the locked solar array to face the Sun and be shadowed by the space shuttle. This case had a maximum of 62-percent shadowing of one wing (~170 $m^2$). It shows a good comparison using a high albedo assumption (justified by cloud cover shown in weather satellite images).

The shadowing algorithms and geometry models predicted shadowing effects at acceptable difference levels from telemetry (within 6 percent of solar array wing ampere-hour capability during a shadowing event). Differences are likely due to a combination of geometric model fidelity and the modeling of the Sun as a point light source (reflection effects were not apparent in the data).

**Find out more about the research of Glenn's Power and Propulsion Office http://space-power.grc.nasa.gov/ppo/about/index.html.**

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